Current Status of Coal Preheating Technology Development for NO_x Reduction from Pulverized Coal-Fired Boilers

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2003 Conference on Selective Catalytic Reduction and Non-Catalytic Reduction for NO_x Control

Pittsburgh, Pennsylvania

October 29-30, 2003

Research Focus:
Strategic use of natural gas in solid fuel combustion applications

- Natural Gas value exceeds heating value
- Relatively small gas inputs provide:
  - Combustion stabilization
    - Startup and load following
    - Low quality, variable quality fuels
    - Control Issues
  - Emissions Reduction
    - NO_x, CO, Particulate
  - Efficiency Improvement

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Project Objectives

- NO_x reduction for PC boilers to below 0.15 lb NO_x / MMBtu without SCR and SNCR
- 25% levelized cost reduction compared to state-of-the-art SCR technology
- Develop/Demo for U.S. (Eastern and Western) utility coals
  - Pilot tests at 3MMBtu/h
  - Commercial prototype tests at 100 MMBtu/h

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Project Team

- GTI– Technology Developer
- All-Russian Thermal Engineering Institute (VTI) – Concept Developer, Burner Design
- Riley Power Inc. (RPI) – a subsidiary of Babcock Power Inc., formerly Babcock Borsig Power – Boiler and Burner Manufacturer, Burner Design & Engineering
- Potential Commercial Host Sites:
  - Southern Company Services
  - Northern Indiana Public Service Corporation

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Project Sponsors

- DOE-NETL
- SMP
- GRI
- Riley Power Inc. (in-kind)

Acknowledgment

This paper was prepared with the support of the U.S. Department of Energy, under Award No. DE-FC26-00NT40752. However, any opinions, finding, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of DOE.

PC PREHEAT
Technical Approach

- Novel PC burner design using gas-fired coal preheating ahead of the primary combustion zone
- Natural gas replaces 3 – 8 % of coal
- Internal combustion staging in burner (LNB)
- Optional - Additional natural gas injection in primary zone, integrated with overfire air in upper combustion chamber.

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PC PREHEAT Technical Approach (Con't.)

FEATURE	PRINCIPLE	IMPLEMENTATION
Coal preheating	Fuel-bound N (FBN) released by heating in the presence of coal volatiles is converted to N_2	Natural gas is burned in rich flame, making hot gases to preheat & pyrolyze coal, releasing FBN, H_2, CO, and hydrocarbons
Internal combustion staging (LNB)	Air staging allows part of combustion under rich conditions, reducing peak temperatures	LNB design using primary, secondary, & tertiary air staging is integrated with preheating feature
(Optional) Additional natural gas injection	Natural gas introduced at base of primary flame can destroy NOx precursors (METHANE de-NOX principle)	Natural gas injected into secondary air duct to impinge on tail of the coal flame

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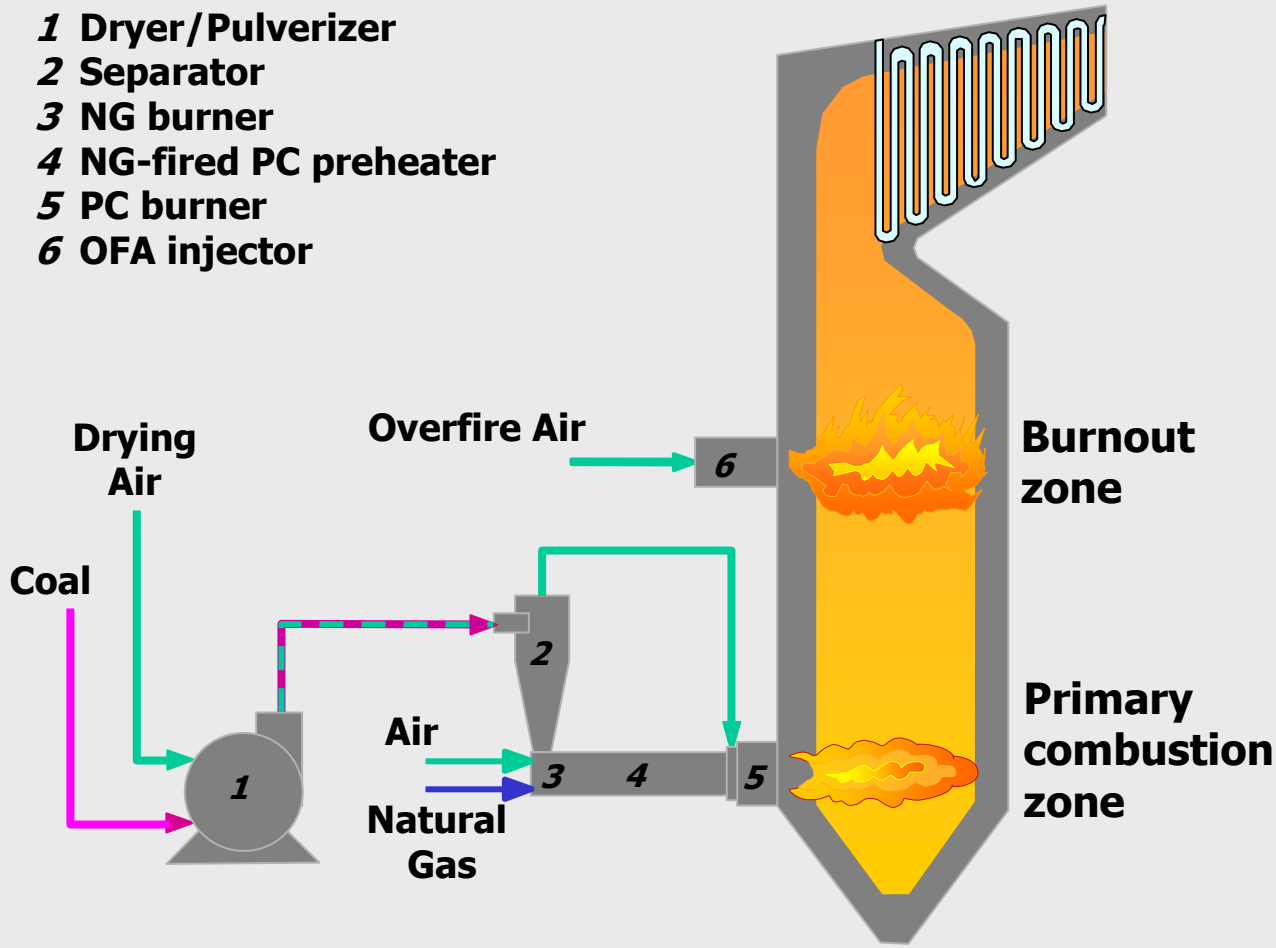
PC PREHEAT NO_x Reduction System

1 Dryer/Pulverizer
2 Separator
3 NG burner
4 NG-fired PC preheater
5 PC burner
6 OFA injector



Development Phase 1
Pilot-Scale Proof of Concept

Task 1. Pilot-scale (3MMBtu/h) design

Task 2. CFD Modeling

Task 3. Fabrication and Installation

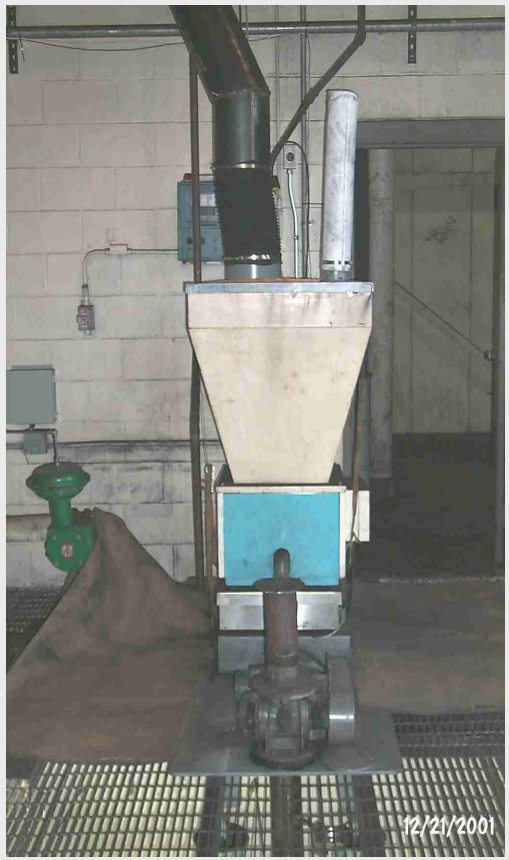
Task 4. Pilot Testing

Task 5. Data Evaluation

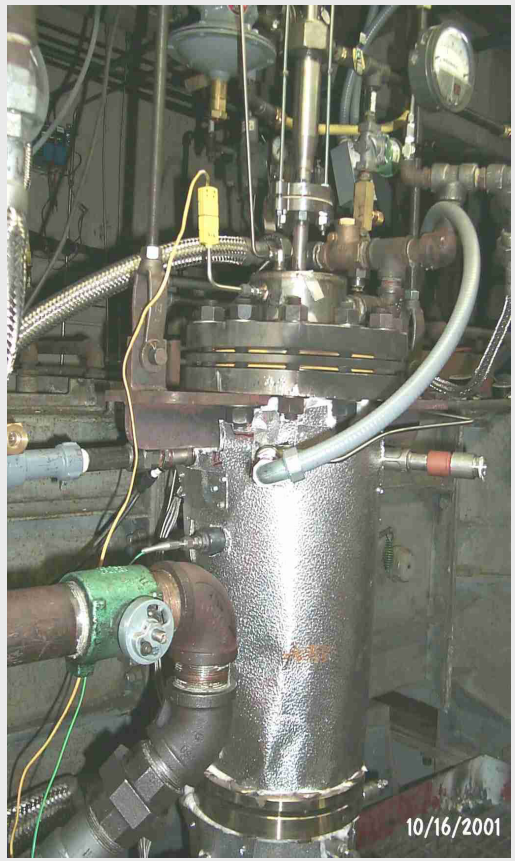
Task 6. Management and Reporting

3 MMBtu/h Pilot at RPI

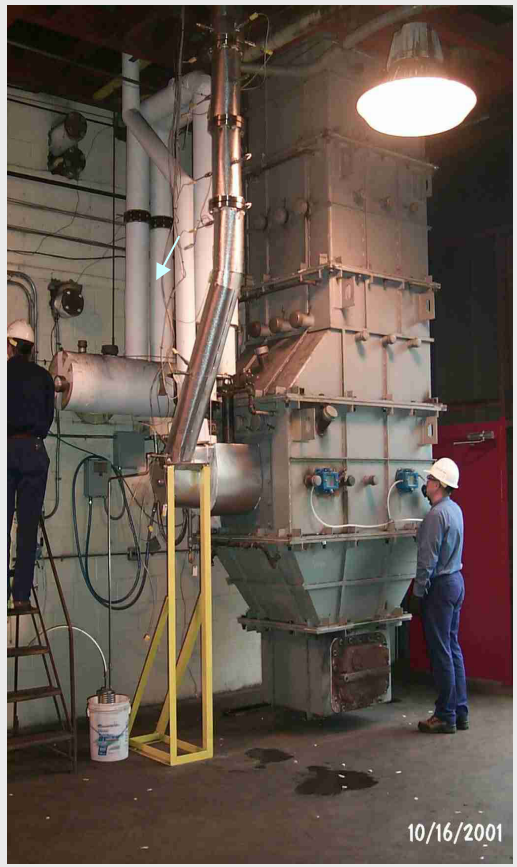
PC Feeder



PREHEAT Combustor



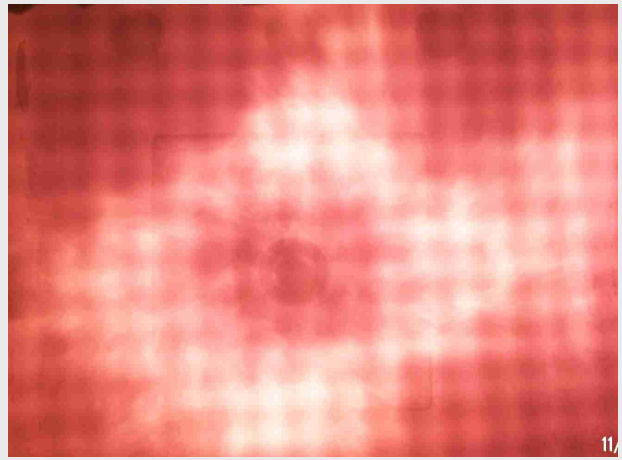
PC Burner and Furnace



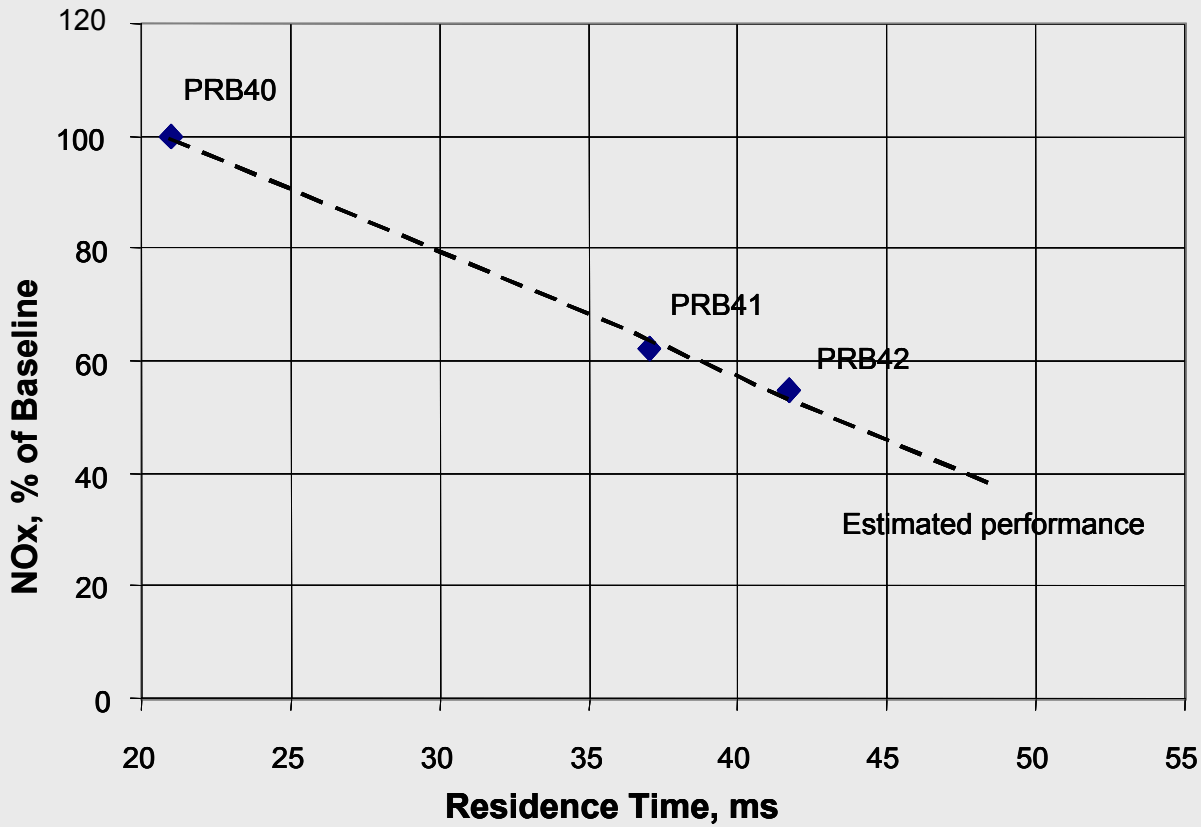
First pilot test results with PRB coal

- Over 5000 lbs of PRB coal fired in over 50 tests at coal rates up to 250 lb/h
- Smooth operation with NOx reduced by over 50 %
- PREHEAT NO_x reduction mechanism different from expected
- Original PC burner design not optimal for fuel composed of hot char and gaseous pyrolysis products

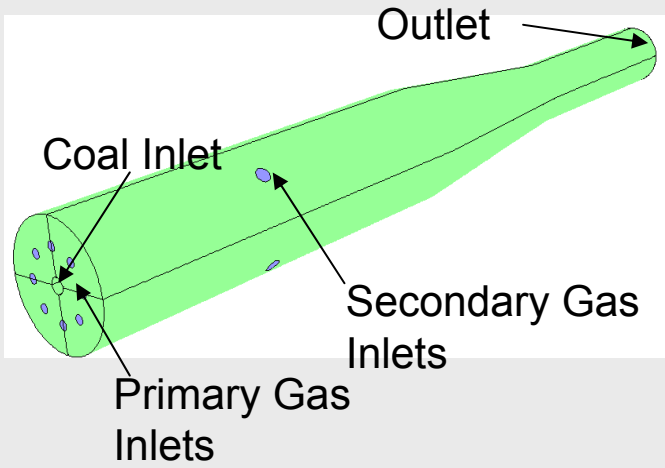
VTI-designed PC burner used for pilot-scale PC Preheat testing produced short, intense flame

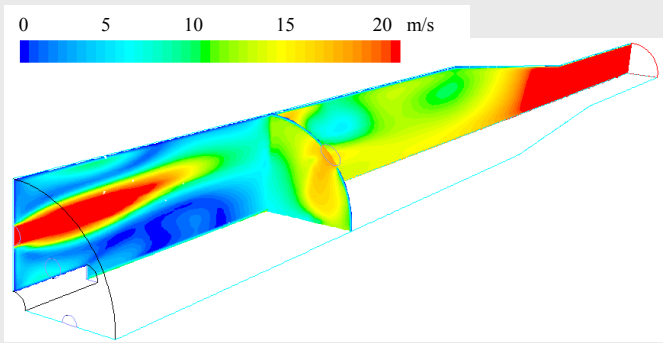


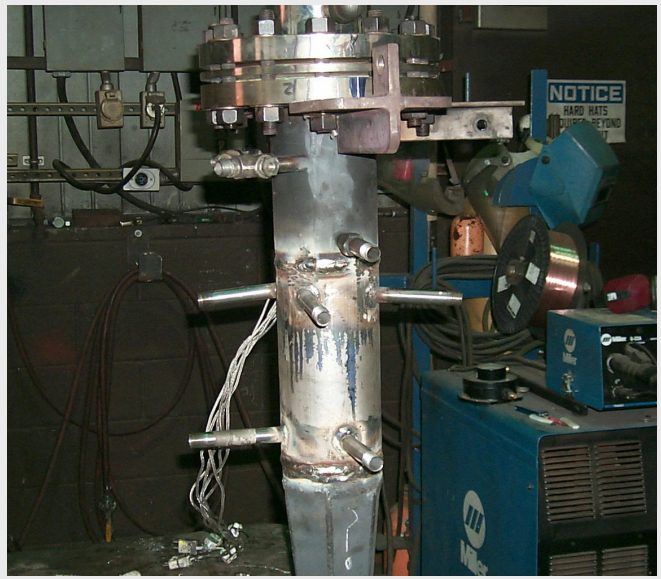
NO_x vs. Combustor Residence Time



PREHEAT Combustor Modeling and Modifications







Modified PREHEAT combustor doubles coal residence time

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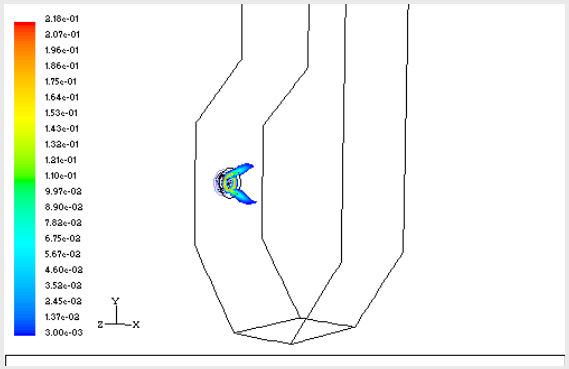
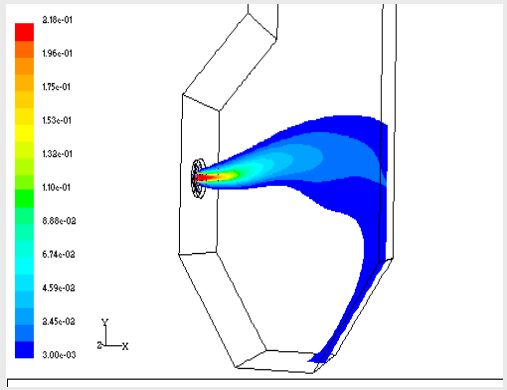
PC Burner Modeling and Modifications

Cross-section of volatile matter in original and modified PC burner flames





- Two burner design approaches selected
  - Air Channel design based on RPI's Combustion Controlled Venturi (CCV™) burner coal nozzle technology
  - Air nozzle design based on GTI's FIR gas burner technology

Pilot Testing – Modified Combustor and Original PC Burner

- 12 additional PRB tests at rates to 250 lb/h
- NO_x reduced to 150 vppm with 36 vppm CO (dry basis, corrected to 3% O_2)
- Need for burner modifications confirmed
- Exploratory testing with caking coal
- Potential methods for caking coal identified
  - Combustor residence time
  - Improved coal/hot gas mixing
  - Secondary combustion zone
  - Steam injection

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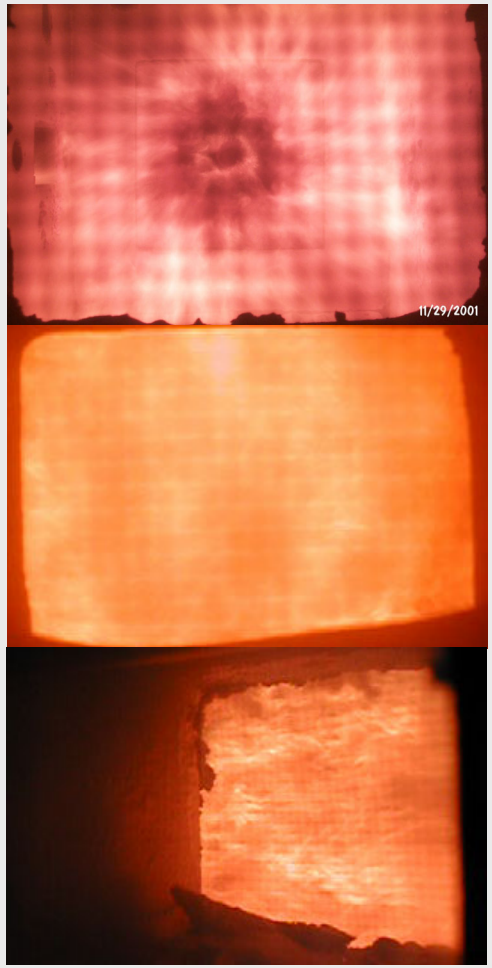
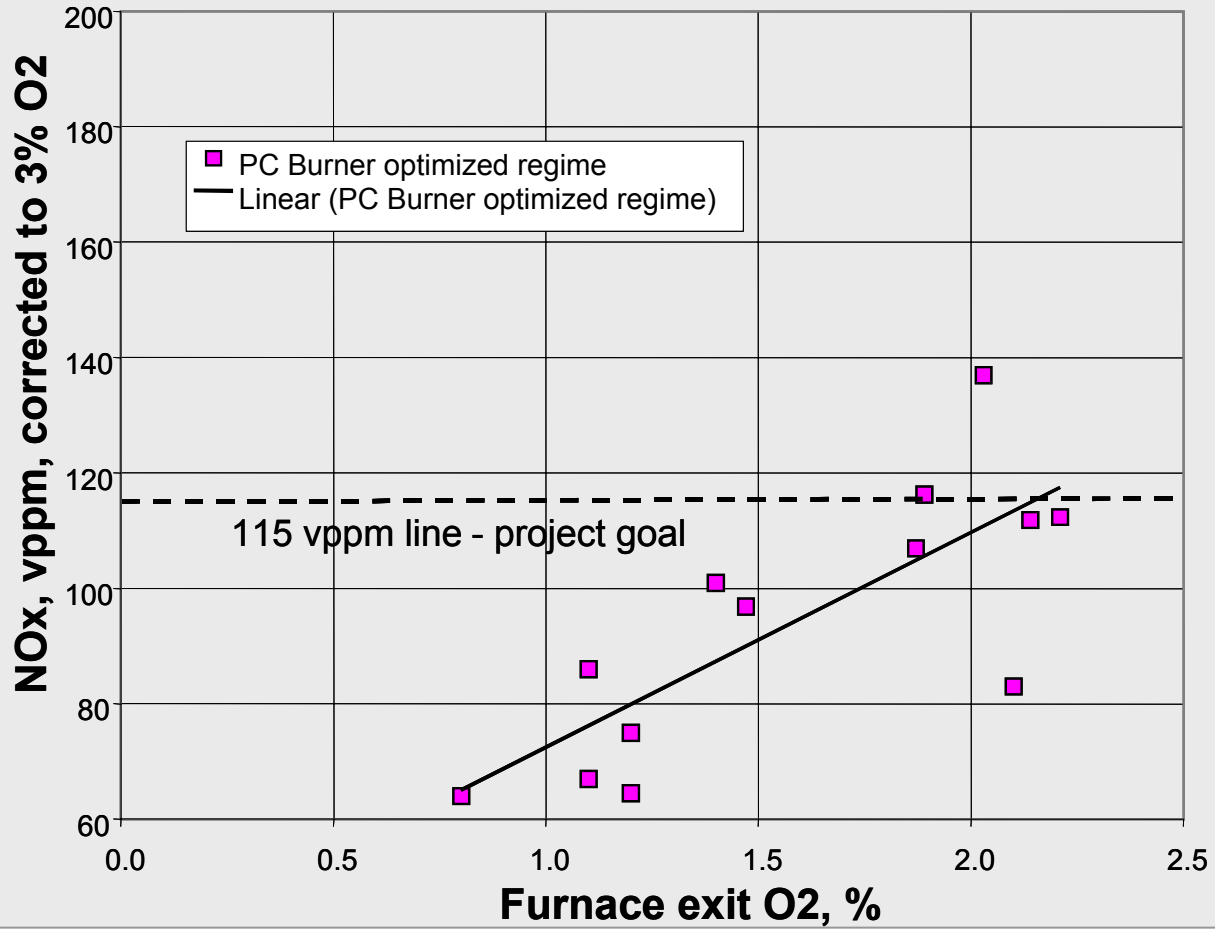
Modified Pilot Testing Channel Burner Design

- 38 additional PRB tests completed
- NO_x reduced to below 100 vppm with 35-112 vppm CO and 2% O_2 at boiler exit
- 115 vppm NO_x (0.15 lb/MMBtu) achieved with gas input as low as 8 % of total thermal input
- No furnace air staging

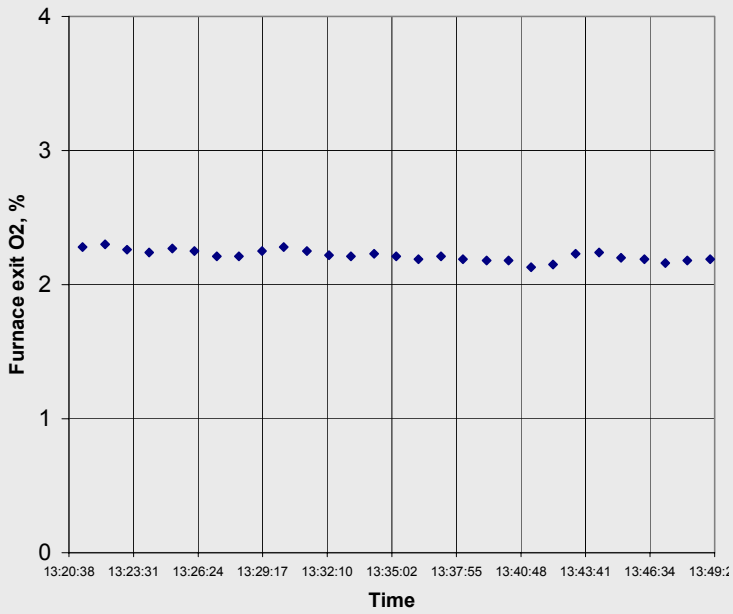


Modified Pilot System Performance-Channel Burner

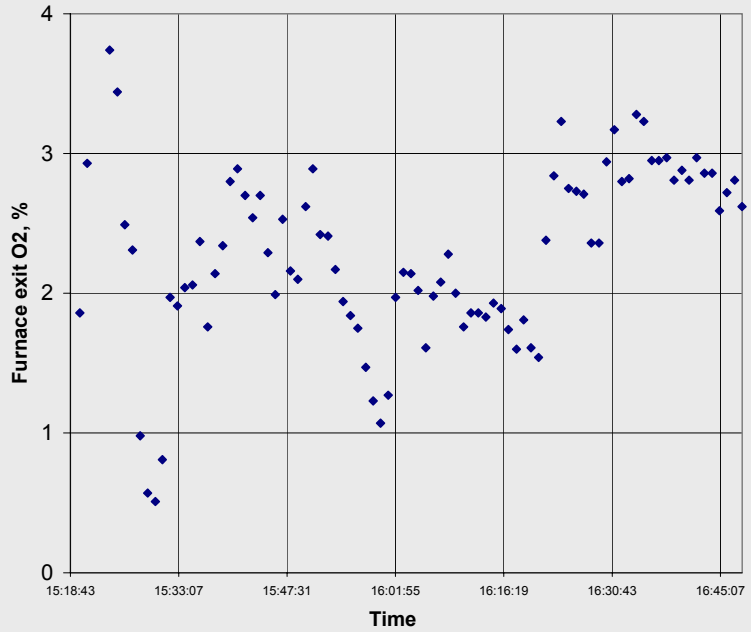


Combustion Stability, Furnace Exit O2 with and without Preheat

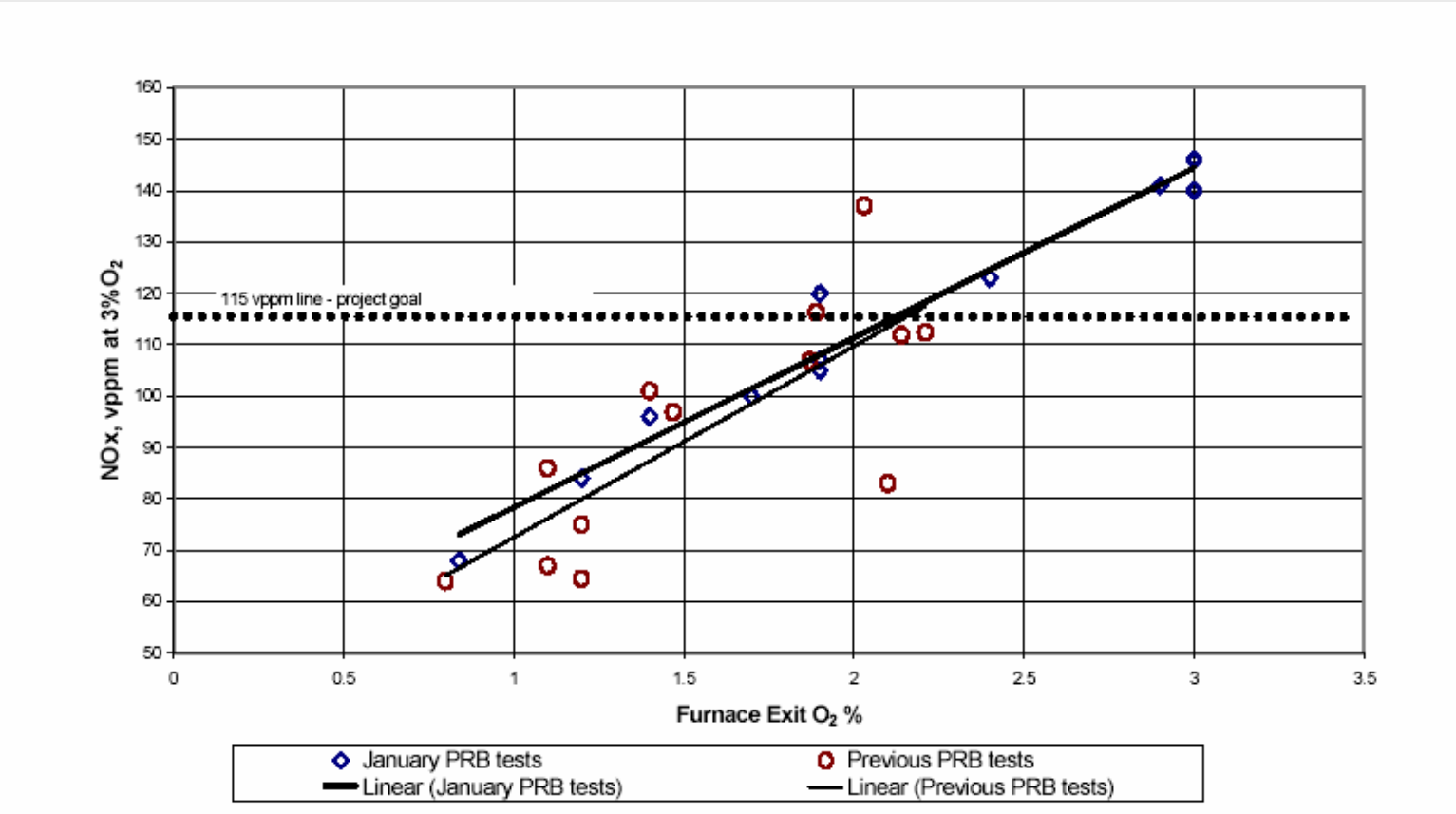
PC Preheat test, furnace exit O2, %



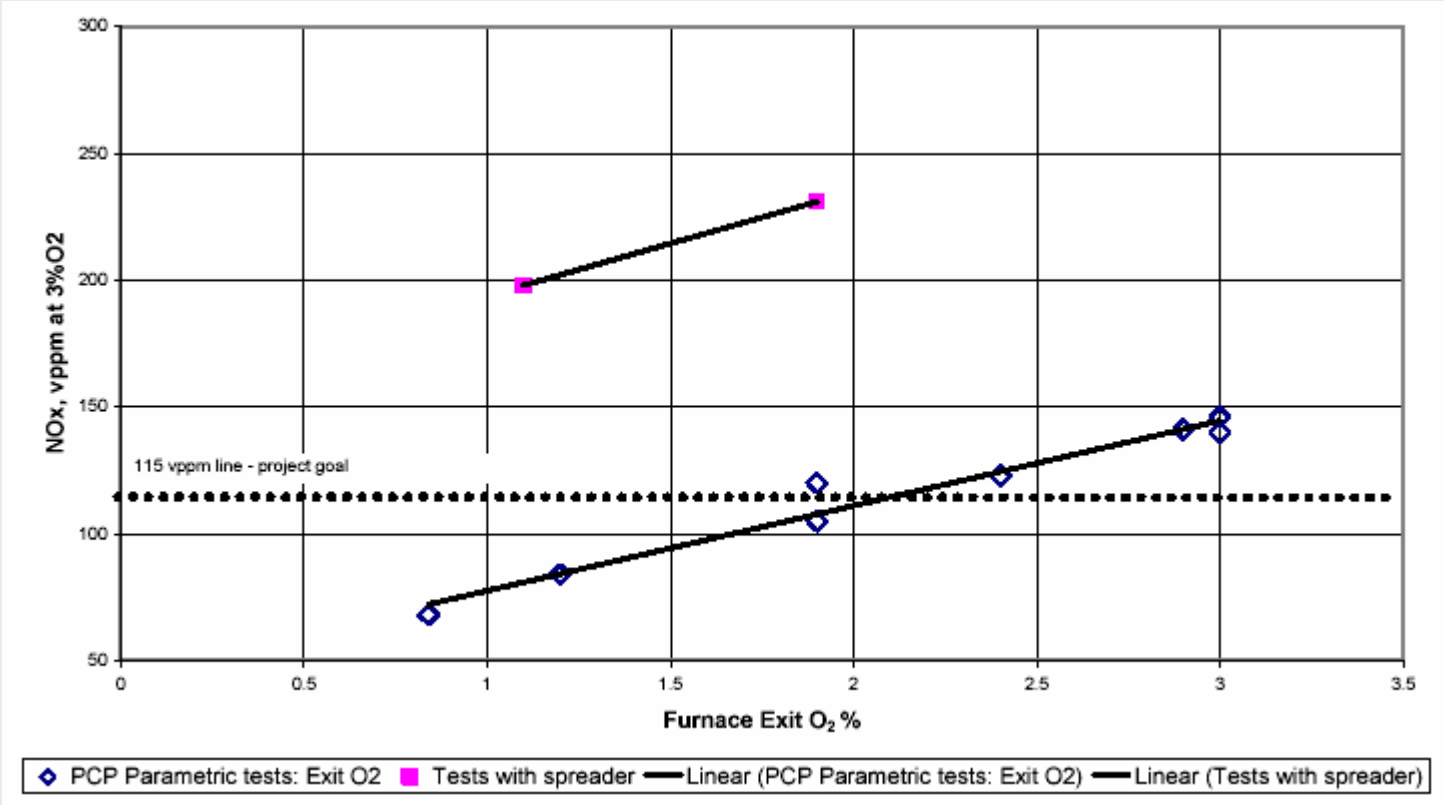
Test without Preheat, Furnace Exit O2, %



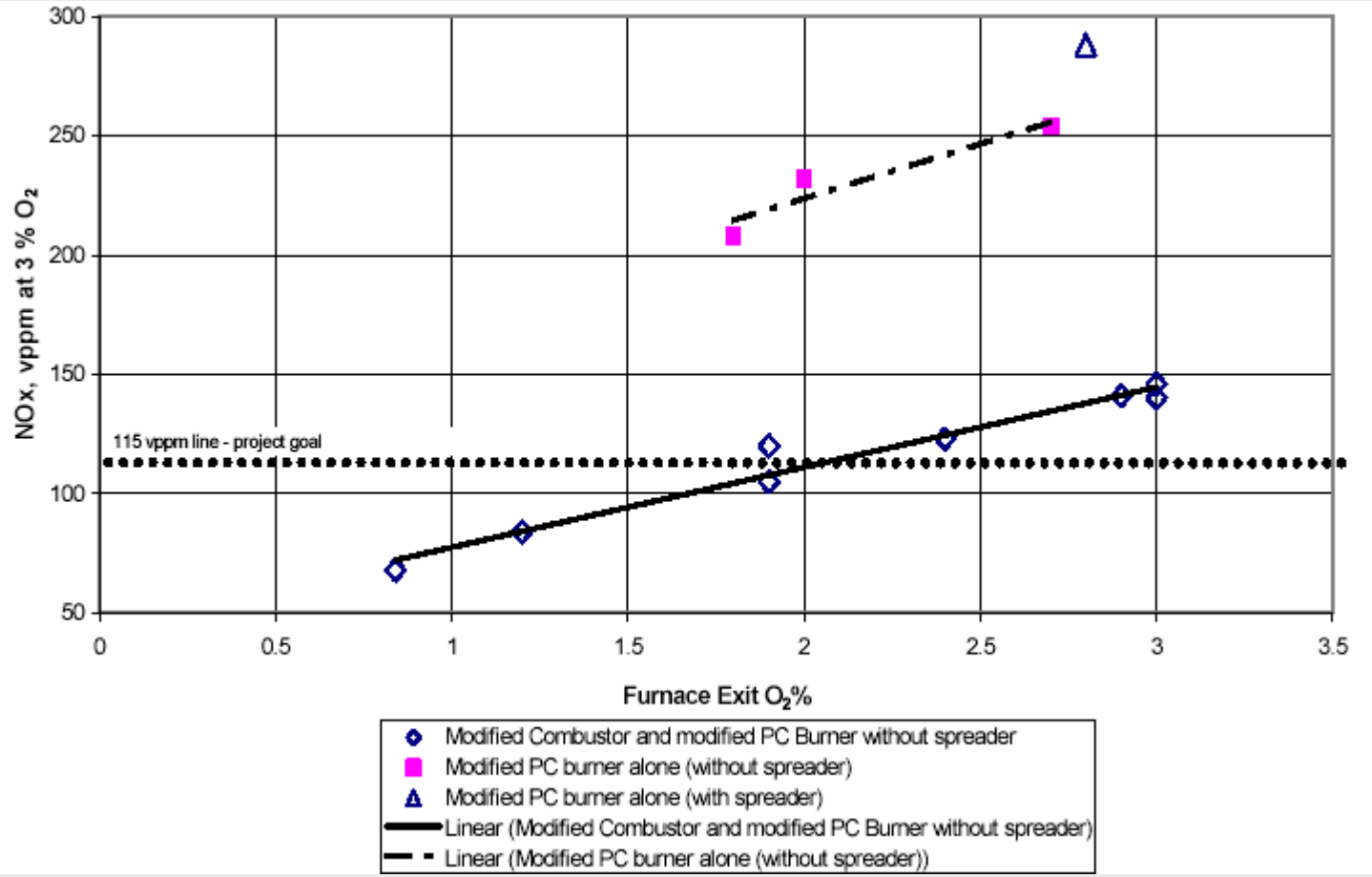
Preheating Tests with Different Batches of PRB Coal



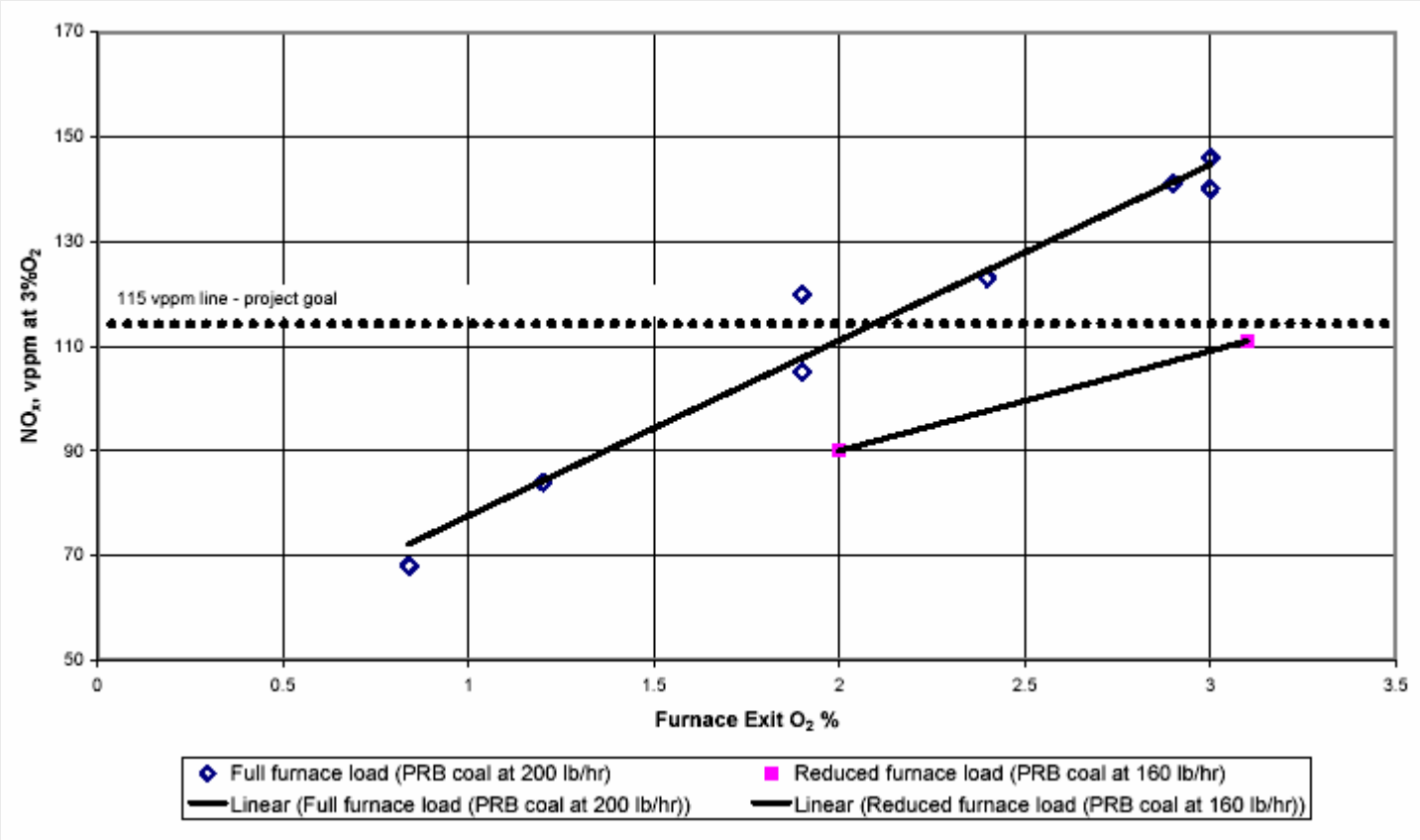
Preheating Tests with and without Coal Spreader



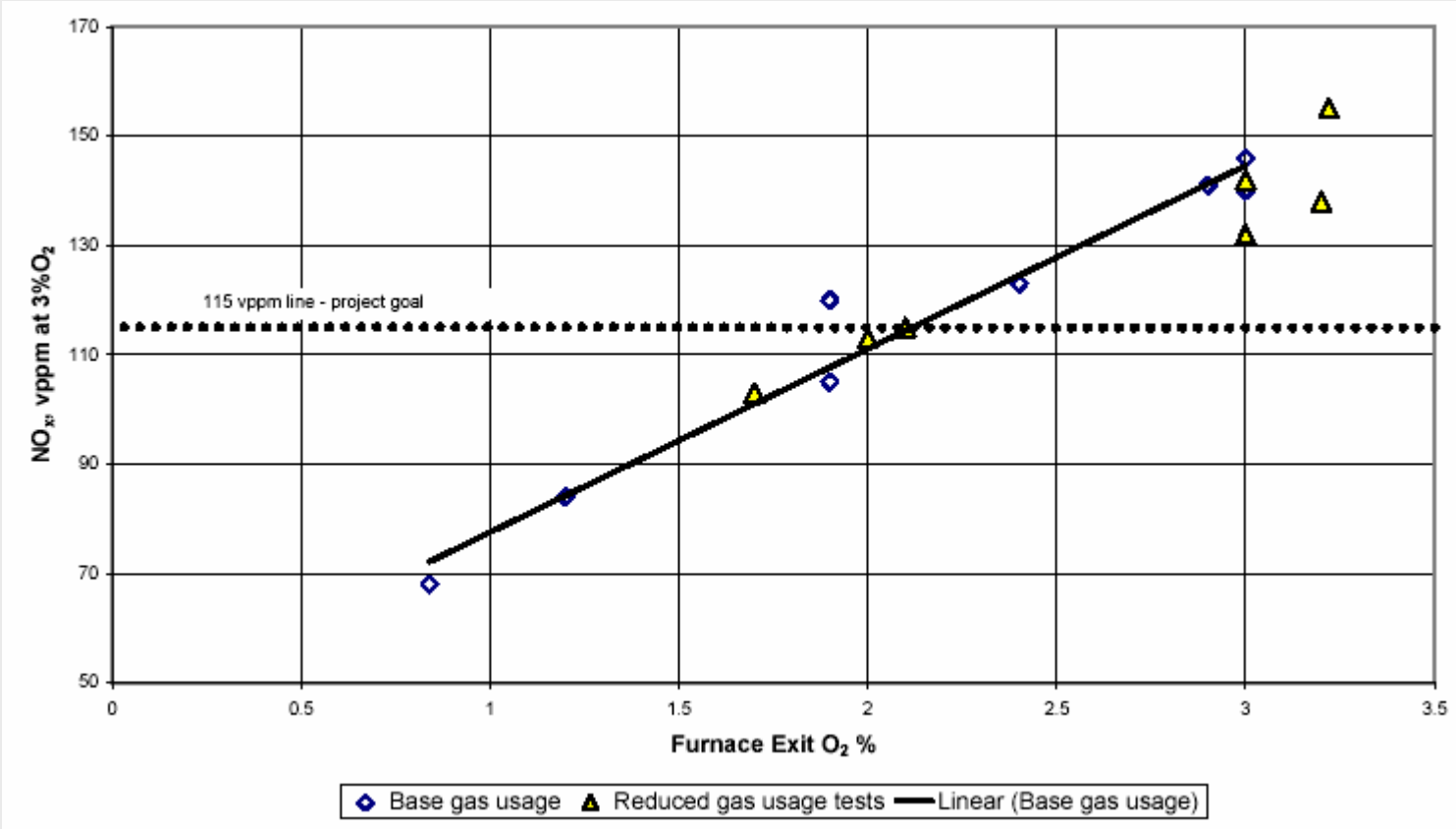
Comparison of Performance with and without Gas Firing



Effect of Reducing Coal firing Rate on NOx at Furnace Exit



Effect of Reduced Preheat Gas Usage on NOx at Furnace Exit



Pilot Testing with Bituminous Coal

- Continuous operation is achieved with caking coal up to 35% load;
- Depositions of partially devolatilized coal occurs at higher loads
- Several approaches are being developed to prevent coal deposition inside the preheater
- Emissions levels are similar to those with PRB coal at comparable firing conditions

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Pilot Testing with Bituminous Coal

- 3 MMBtu/h preheat combustor was relocated to a horizontal orientation and integrated as a part of the burner to simulate 100 MMBtu/h Unit arrangement
- CFD modeling of the new 3 MMBtu/h preheater is completed
- Pilot testing of the horizontal arrangement is under way
  - Preheater/burner integration
  - Performance
  - Firing bituminous coal without depositions

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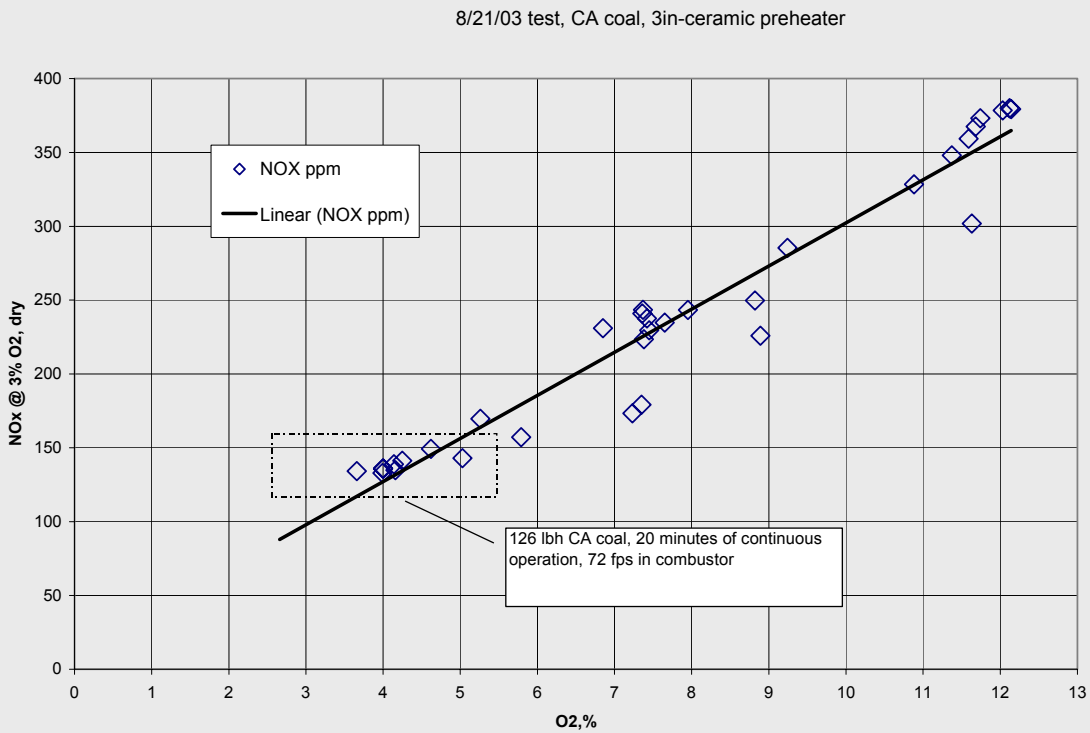
Pilot Testing with Bituminous Coal

- The testing goal is to determine approaches for deposition and agglomeration free operation
- Continuous operation was achieved at up to 70% load in horizontal unit
- Further pilot testing is planned to achieve continuous operation at 100% load
- NO_x results for caking coal are promising

Pilot Testing with Bituminous Coal



Development Phase 1 Pilot-Scale Proof of Concept Results

- NOx levels down to 0.15 lb/MMBtu and below without OFA and without post-combustion controls are achievable with PC PREHEAT
- Smooth operation and superior combustion stability have been demonstrated
- Ability to operate at 10 to 15% excess air levels has been demonstrated
- Validation Phase 2, 100MMBtu/h Unit demonstration has been initiated

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100 MMBtu/h Unit: Project Status

- CFD Modeling in support of 100MMBtu/h design is under way
- Inspection and repair of the 100 MMBtu/h Coal Burner Test Facility is 95% complete
- Manufacturing of Preheater and Burner is under way
- Pilot scale testing in support of 100 MMBtu/h work is under way
- Firing tests of 100 MMBtu/h Unit are scheduled for December 2003

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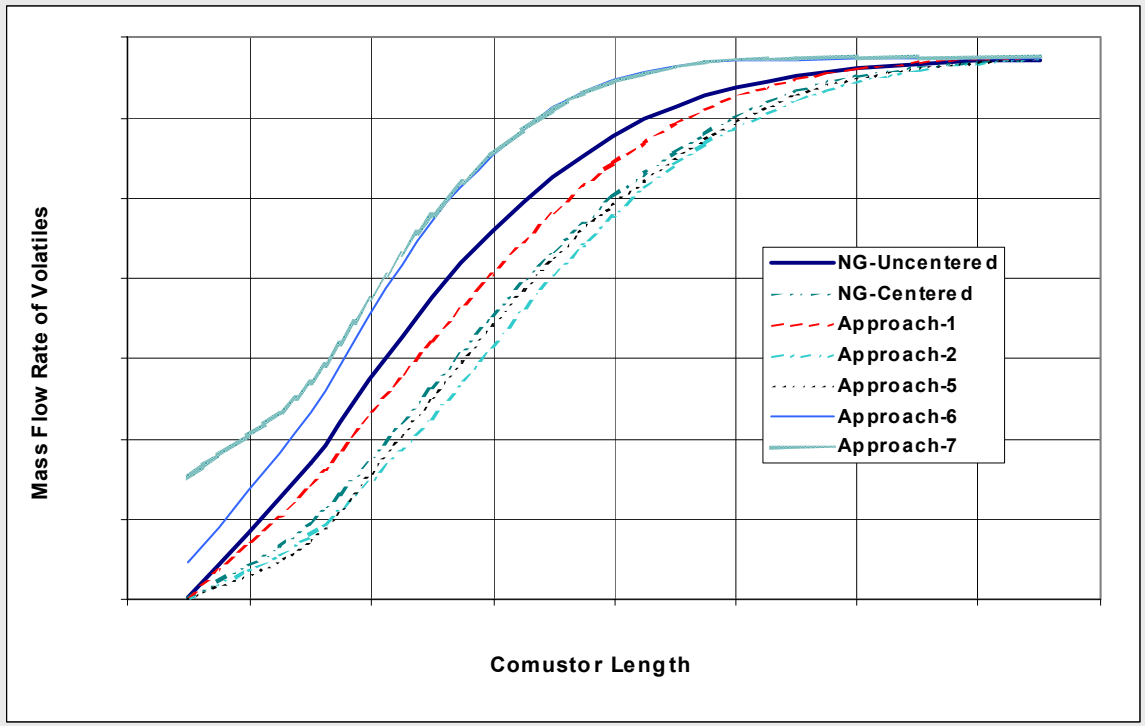
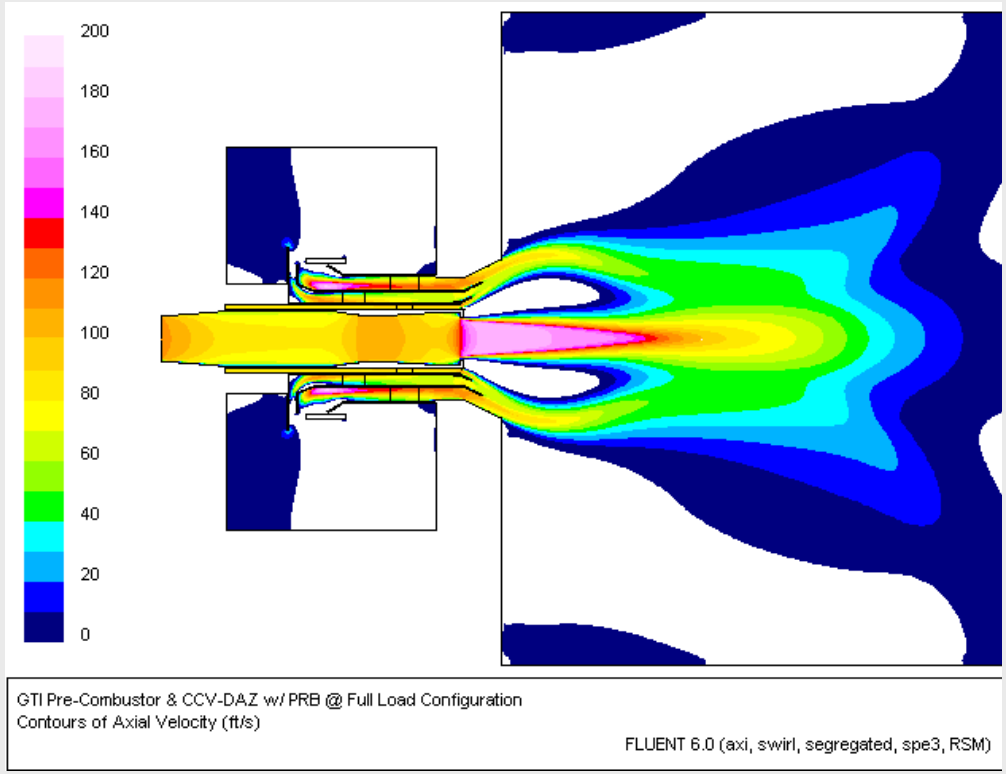
100 MMBtu/h Unit: Preheater CFD Modeling is completed



Distribution of the mass flow rate of volatiles along the preheater centerline for the 100MMBtu/h PRB coal case.

100 MMBtu/h Unit: Burner CFD Modeling is under way



CFD Results on Near Burner Aerodynamics with PRB Coal Firing, Axial Velocity Contour

The Path Forward

TASK 1

GOAL: Prove burner design concept at pilot scale

1.1 Pilot-scale design
1.2 CFD modeling
1.3 Pilot-scale equipment fabrication & installation
1.4 Pilot-scale testing-caking coal
1.5 Pilot-scale data evaluation
1.6 Management & reporting

Task 1 report

TASK 2

GOAL: Demonstrate system at 100 million Btu/h scale & build a commercial burner ready for field demonstration

2.1 Commercial Prototype Engineering design
2.2 Baseline Data Review
2.3 Commercial Prototype Construction
2.4 Commercial Prototype Testing
2.5 Data Processing and Evaluation
2.6 Commercialization Plan Development
2.7 Design and Fabrication of Commercial Burner System
2.8 Management & reporting

Task 2/Final report